G. QUIRK, TEST GEAR

INSTRUCTION MANUAL
FOR
MODEL 440
POWER METER

the narda microwave corporation

PLAINVIEW, L. I., NEW YORK

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FOR
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POWER METER

THE NARDA MICROWAVE CORPORATION

December 12, 1960

POWER – MILLIWATTS
DECIBELS
the narda
microwave
corporation
POSITIVE
OFF
NEGATIVE
200
100
200
100
CHARGING
BATTERY
CHECK
BIAS RANGE
MA
INPUT
ZERO SET
.01
.03
0.1
0.3
1.0
3.0
10.
MW
-20
DB
-15
-10
-5
0
+5
+10
DB
MW
3
4
6
9
0
OFF
18
POWER METER
NARDA MODEL 440

FIGURE 1

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1. INTRODUCTION

The microwave power meter is used in conjunction with a sensing element to obtain accurate direct readings of CW or pulse power automatically. Frequency dependence is inherent only in the detector mount used. Any sensing element having either a positive or negative temperature coefficient and capable of operating at 100 or 200 ohm levels with bias currents up to 18 madc may be used. Seven power ranges permit direct power readings from 0.001 to 10.0 mw. or from -30 to +10 dbm. Higher power levels may be measured by use of directional couplers and/or calibrated attenuators.

2. SPECIFICATIONS

Scales	Seven ranges, front panel selection: 0.01, 0.03, 0.1, 0.3, 1.0 3.0, 10.0 milliwatts full scale; -30 to -20, -25 to -15, -20 to -10, -15 to -5, -10 to 0, -5 to +5, 0 to +10 dbm full scale.
Bias Current	0 - 18 milliamperes d-c.
External Sensing Element	Thermistors or bolometers with the following characteristics: a. positive or negative temperature coefficient, b. 100 or 200 ohm operating resistance c. bias current from 0 to 18 ma.
Accuracy	±3% of full scale reading

Power	**Battery, 12 volts nominal Gulton 10V0.500. Fully charged battery will operate unit at least 12 hours.**
Built-in Charger Power Requirements	**115 or 230 volts 50-60 cps., approximately 2 watts.**

IMPORTANT: Recharge period for a fully discharged battery is 16 hours. Power meter may be operated while battery is being charged without detriment to its performance; however, the charging period will increase. Battery of a non-operating unit may be continuously charged up to 90 days without damage to the battery.

3. FUNCTIONAL DESCRIPTION

Model 440 consists primarily of a self-balancing audio bridge.

This self-balancing circuit acts to maintain the specified operating resistance of the external thermal sensing element which is inserted in one branch of the bridge. Since the feedback to the bridge is audio power, any increase of r-f or d-c power into the element will be accompanied by an equivalent decrease in audio level. By the substitution method it is the change in audio power which is measured to determine the r-f power. To make a power measurement the d-c bias current is first adjusted to zero the meter -- this places the audio power at a known level. With the application of r-f power an equivalent amount of audio power is automatically removed resulting in an upscale meter deflection which directly indicates r-f power.

4. THEORY OF OPERATION

The components of the self-balancing bridge are essentially those shown in figure 2. Basically, the circuit consists of a bridge (with the thermal sensitive element forming one arm of the bridge), a high-gain audio amplifier, a feedback circuit to provide oscillation,

and a d-c bias network. Output of the audio amplifier is monitored by a voltmeter.

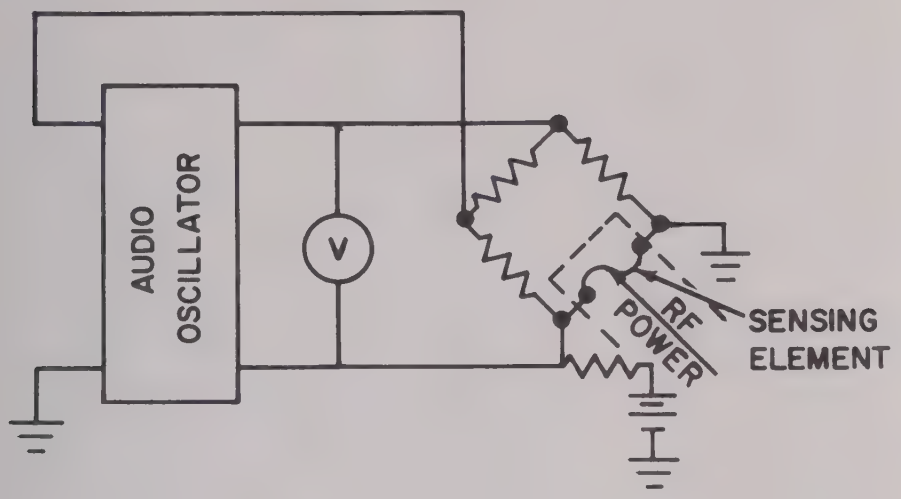

Figure 2

Initially the resistance of the thermal sensitive element is considerably different from that of the operating resistance of the bridge. As a result of the high feedback factor of the circuit large amplitude oscillations occur which rapidly change the resistance of the element. Equilibrium or "zero" reading is obtained when the element resistance becomes slightly different from that of the operating resistance of the bridge.

Since the bridge circuit tends to maintain the element's resistance at its specified operating value, any increase of power in the element causes an equivalent decrease of audio power. This particular characteristic of the circuit is utilized in the following manner: The voltmeter circuit across the output of the oscillator measures the audio bridge voltage. A d-c current is supplied to the meter in the forward direction, while the rectified audio is applied in the reverse direction. Therefore, for a decrease in audio

signal an upscale deflection of the meter occurs. The voltmeter scale calibrated in power units measures power directly.

5. CONTROLS AND CONNECTIONS

A. Summary -

SELECTOR SWITCH	100Ω positive, 200Ω positive OFF, 200Ω negative, 100Ω negative.
BATTERY CHECK SWITCH	Momentary left position.
POWER RANGE SELECTOR	0.01 to 10 mw.
ZERO SET	Coarse and fine adjustments
BIAS RANGE AND SWITCH	OFF, 0 to 18 ma.
INPUT	BNC receptacle on front panel.
ELEMENT CURRENT	Jack on rear panel
CALIBRATION JACK	Jack on rear panel.
INDICATOR LAMP	Indicates charger operation.

B. Description and Function-

SELECTOR SWITCH

A five position rotary switch permits the operator to select the resistance and temperature coefficient of the sensing element used, either 100Ω positive or negative, or 200Ω positive or negative. The center OFF position removes all power except that for the battery charger.

BATTERY CHECK SWITCH

The horizontally oriented lever switch has a momentary position to the left. When this switch is held in the BATTERY CHECK position the battery voltage is indicated by the panel

meter. A red line on the top scale of the meter marked BATTERY MINIMUM corresponds to a battery voltage of 11.5 volts.

POWER RANGE SELECTOR

A seven position rotary switch permits the operator to select the appropriate meter scale for the power range in which measurements will be made.

ZERO SET

The dual concentric potentiometer permits coarse and fine adjustments of the element bias for the purpose of zeroing the meter.

BIAS RANGE AND SWITCH

This potentiometer with a switch at the extreme counter clockwise position permits the operator to apply and to adjust the bias current to the approximate value required for zeroing the meter.

INPUT

The output of the detector mount is connected to this receptacle.

ELEMENT CURRENT

This jack is used for checking sensing element current.

CALIBRATION JACK

A vacuum tube voltmeter is connected to this jack when calibrating the unit.

C. Charger Transformer T3-

Provision has been made for either 115 volt or 230 volt operation of the internal battery charger. (See figure 3.) As shipped from the factory the jumpers on the transformer are placed between terminals 1 and 3, and 2 and 4 to permit operation from a nominal 115 volt power line(figure 3a). The dual primary transformer windings are in parallel and properly phased for this operation. For operation from a nominal 230 volt power source remove both jumpers; disconnect the wire from terminal 2, and connect it to terminal 4; and insert jumper diagonally between terminals 2 and 3 (figure 3b). This will place the transformer primary windings in series and properly phased for nominal 230 volt operation.

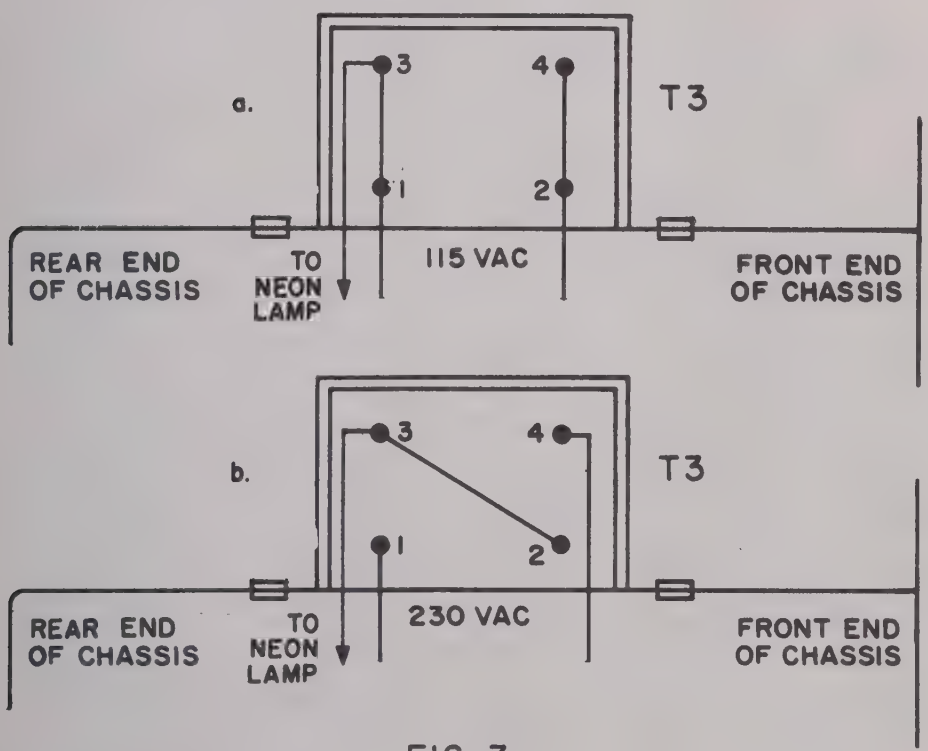

FIG. 3

6. SEQUENCE OF OPERATION

The following procedure should be followed in order not to damage the unit or the sensing element.

(1) Select an appropriate detector mount, either a waveguide or a coaxial type, and a sensing element.

(2) Set the BIAS RANGE AND SWITCH to the OFF position.

(3) Connect the audio cable from the detector mount to the INPUT connector located on the front panel.

(4) Set the SELECTOR SWITCH to the appropriate ohmic value and temperature coefficient and the POWER RANGE SELECTOR to 10 mw., and adjust the ZERO SET controls to their center position.

(5) Adjust the BIAS RANGE AND SWITCH to zero the meter approximately. Carefully adjust the ZERO SET coarse and fine controls until the meter indicates exactly zero.

(6) If a slight indication is obtained (or if no indication is evident), remove the r-f power applied, and re-adjust the BIAS RANGE AND SWITCH and ZERO SET controls until an approximate indication of 0.85 on the top scale is obtained; then set the POWER RANGE SELECTOR one step downward, and adjust ZERO SET controls to zero the meter. Re-apply r-f power, and check meter for any indication. (Setting the meter to 0.85 before switching the POWER RANGE SELECTOR one step downward will zero the meter approximately for the next lower power range and prevent slamming of the meter indicator especially when switching down to the more sensitive lower power ranges.)

The above procedure and step (5) should be repeated until

a good indication of r-f power is obtained.

(7) After use the BIAS RANGE AND SWITCH and the SELECTOR SWITCH should be set to the OFF position,

(8) The battery charger should be energized at intervals so that the unit will be ready for operation whenever required. This is accomplished by connecting the unit to the appropriate power source.

(9) In the use of the lower power ranges (.01 to 0.1 mw. full scale) of the meter, care must be exercised in obtaining and maintaining stable thermal operating conditions for the sensing element. In addition, the lower current elements are recommended for use on these lower ranges. The sensing elements are 200 ohm low power, high sensitivity units and are available in the crystal and disc configurations. Extra caution must be observed in the use of these elements because of their lower burn-out power level, but with their judicious utilization, lower scales of the power meter become more useful in a practical sense because of the drift reduction that is effected. Typical low current elements are the Narda N610B-4.5 and PRD610A bolometers in the crystal configuration and the Narda N603-4.5 and PRD631C bolometers in the disc configuration.

7. CALIBRATION PROCEDURE

A. Battery Check -

A battery voltage check should be made before proceeding with the calibration. Figure 4 shows the typical battery voltage variations when the charger is either operating or not operating. This variation of voltage will not affect the

calibration of the unit as long as the voltage is permitted to stabilize in any condition. A voltage variation can only result in meter-drift — especially evident during the first few minutes of operation when the charger is turned ON or OFF.

B. Metering Circuit -

Connect a vacuum-tube-voltmeter of a high impedance type to the calibration jack at the rear of the unit. With the Power Meter in operation on the 1 mw scale and using a 200 ohm bolometer or thermistor element in a detector mount, adjust the BIAS RANGE control until the VTVM indicates 0.200 volts. Adjust the potentiometer R56* until the Power Meter indicates full scale. Readjust the BIAS RANGE control until the VTVM indicates 0.490 volts. Adjust potentiometer R49 until the Power Meter indicates zero. Recheck these readings several times because there exists interaction between the two adjustments. This completes the calibration of the metering circuit.

C. Bridge Circuit -

Place a decade resistance box across the INPUT terminals and check the resistance at which the bridge operates for each of the four possible operating conditions: 100 and 200 ohms with positive or negative temperature coefficient. This operating resistance can be determined by observing the resistance at which the bridge oscillates and then stops oscillating as the resistance of the decade box is changed in steps of one ohm or less. Oscillation will be indicated by an off-scale, down-scale reading of the Power Meter; and non-oscillation will be indicated by an off-scale, up-scale reading. Adjusting potentiometer R12, R14, and R15 will correct the operating resistance of the bridge for the four possible operating conditions.

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*To locate adjusting potentiometer see schematic on page 13

8. ACCURACY

Inasmuch as a direct r-f method for checking power meter accuracy to within the specified±3% of full scale limits is tedious and requires rather elaborate equipment, some other methods should be considered which requires only low frequency measurements of voltage and resistance.

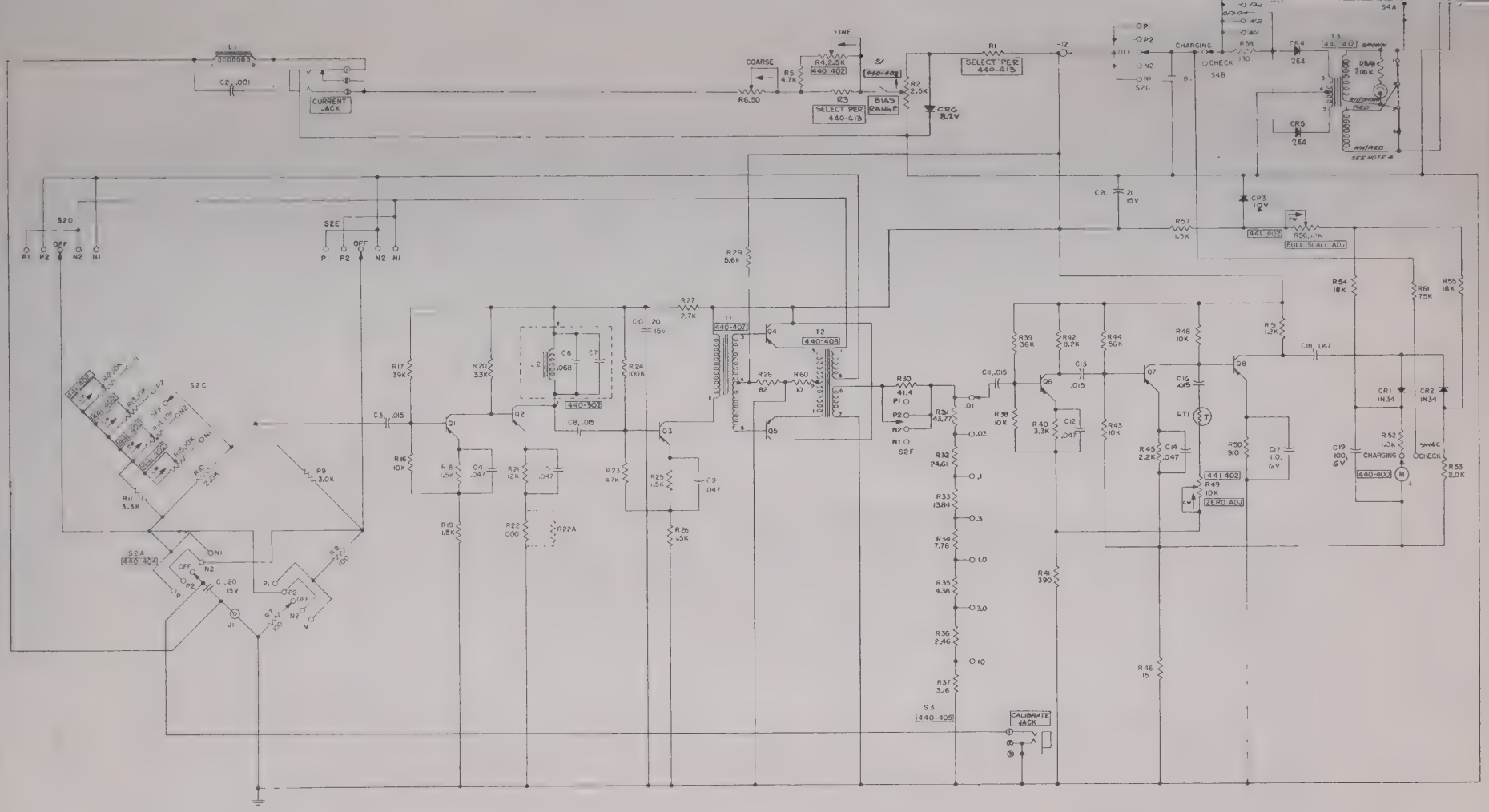
To review, the power meter consists of a voltmeter and a self-balancing bridge. The self-balancing bridge maintains the operating resistance of the sensing element at a given value (100 ohms or 200 ohms). Over the entire operating range of the power meter the change in this operating resistance is negligible. The voltmeter measures the audio voltage across the bridge circuit; hence the signal required to balance the bridge is by power substitution inversely proportional to the power applied to the sensing element.

Power applied to the sensing element may be expressed as E^2/R. Accuracy of E^2 and R terms determine the overall measuring accuracy. The standard calibration procedure for the Narda Model 440 Power Meter permits adjustment of the element resistance to within 0.1% when using a decade resistance box of 0.01% accuracy. Therefore the maximum total error for R is 0.11%. Two additional adjustments of the voltmeter circuit gain permit the adjustment of the E term to within the accuracy of the calibrating voltmeter which must be better than 0.1%. This calibrating meter accuracy is necessary only at two discrete points on the scale. The Narda Power Meter has a meter movement linearity of 1% of full scale. Selected resistors in the voltage divider network used for range switching are held to 0.2%. Voltage measurement is made of the total voltage applied across the bridge, and therefore the accuracy of the 100 ohms or 200 ohms resistor (see schematic diagram) in the fixed arm of the bridge directly affects the voltage measurement. Each of these two resistors is held held within 0.1%. Since the E term appears in the second power in the power equation, a 1.4% voltage error (0.1% + 1.0% + 0.1% + 0.2%) will result in a 2.81% power error. Upon the addition of the

0.11% error possible for R the overall accuracy becomes at worst 2.92% of full scale.

The only remaining sources of error not checked in the instrument are the self-balancing oscillator and the voltmeter circuit linearities. Careful measurements of the signal input vs. signal output of these circuits show no detectable deviation from linearity over the entire operating range.

A final consideration should be that of temperature variation. All circuits in the Power Meter have been temperature compensated for operation at an ambient temperature range of $60^{\circ}F$ to $115^{\circ}F$. Even so, the ultimate in accuracy will be achieved if the calibration procedure is carried out at the temperature at which the unit is expected to be operated. Large temperature variations will affect the calibration and therefore the overall accuracy of the unit.



NOTES:
1. ALL RESISTORS IN OHMS
2. ALL CAPACITORS IN MICROFARADS, 200V, UNLESS SPECIFIED
3. THIS DWG APPLICABLE FOR UNITS 400 AND UP

4.(a) FOR 115 V OPERATION ADD JUMPERS AS ABOVE FROM 1703 & 2704.
(b) FOR 230V OPERATION REMOVE JUMPER FROM 143 & 244 & CONNECT JUMPER PER DOTTED CONNECTION BETWEEN 243.

FIGURE 5

SCHEMATIC, POWER BRIDGE

nard

SIZE E 440-504 E

TABLE OF REFERENCED PARTS

FOR

NARDA MODEL 440

REFERENCE DESIGNATION	PART NO.	DESCRIPTION	MANUFACTURER
B1	10V0.500	Battery, 12v, 500mah	GULTON INDUSTIES
C1, C10, C20	30D167	Capacitor, 20uf, 15v	SPRAGUE
C2	109P10292	Capacitor, .001uf, 200v	SPRAGUE
C3, C8, C11, C13, C16	109P15302	Capacitor, .015uf, 200v	SPRAGUE
C4, C5, C9, C12, C14, C18	109P47302	Capacitor, .047uf, 200v	SPRAGUE
C17	30D121	Capacitor, 1uf, 6v	SPRAGUE
C19	30D135	Capacitor, 100uf, 6v	SPRAGUE
CR1, CR2	1N34	Diode	---
CR3	MEZ10T10	Diode	INT'L. RECT. CORP.
CR4, CR5	2E4	Diode	INT'L. RECT. CORP.
CR6†	---	Diode	---
I1	NE-51	Lamp, Neon	---
J1	UG-1094/U	BNC Receptacle	---
J2	13B	Jack	SWITCHCRAFT
J3	12B	Jack	SWITCHCRAFT
L1	440-406	Choke	NARDA
*	440-302	Tuned Circuit Ass'y.	NARDA
M1	440-400	Meter	NARDA
Q1 thru Q8	2N270	Transistor, PNP	R. C. A.
R1†, R3†	---	Resistor	---
R2, S1	440-403	Potentiometer, Switch	NARDA

† Factory matched components.

* Parts which can be replaced at factory only. All other parts can be replaced by customer.

MODEL 440 (continued)

REFERENCE DESIGNATION	PART NO.	DESCRIPTION	MANUFACTURER
R4, R6	440-402	Dual Potentiometer	NARDA
R5	EB-1/2	Resistor, 4.7KΩ ±5%	ALLEN BRADLEY
R7, R8	440-R7,R8	" 100Ω ±0.5%	NARDA
R9	440-R9	" 3.0KΩ ±0.5%	NARDA
R10, R53	EB-1/2	" 2.0KΩ ±5%	ALLEN BRADLEY
R11, R20, R40	EB-1/2	" 3.3KΩ ±5%	ALLEN BRADLEY
R12,R13,R14, R15,R49,R56	441-402	Potentiometer	NARDA
R16,R38,R43, R48	EB-1/2	Resistor, 10KΩ ±5%	ALLEN BRADLEY
R17	EB-1/2	" 39KΩ ±5%	ALLEN BRADLEY
R18,R19,R25 R26,R57	EB-1/2	" 1.5KΩ ±5%	ALLEN BRADLEY
R21	EB-1/2	" 12KΩ ±5%	ALLEN BRADLEY
R22,R52	EB-1/2	" 1KΩ ±5%	ALLEN BRADLEY
R23	EB-1/2	" 47KΩ ±5%	ALLEN BRADLEY
R24	EB-1/2	" 100KΩ ±5%	ALLEN BRADLEY
R27	EB-1/2	" 2.7KΩ ±5%	ALLEN BRADLEY
R28	EB-1/2	" 82Ω ±5%	ALLEN BRADLEY
R29	EB-1/2	" 5.6KΩ ±5%	ALLEN BRADLEY
R30	440-R30	" 41.4Ω ±0.5%	NARDA
R31	440-R31	" 43.77Ω ±0.5%	NARDA
R32	440-R32	" 24.61Ω ±0.5%	NARDA

REFERENCE DESIGNATION	PART NO.	DESCRIPTION	MANUFACTURER
R33	440-R33	Resistor, 13.84Ω ±0.5%	NARDA
R34	440-R34	" 7.78Ω ±0.5%	NARDA
R35	440-R35	" 4.38Ω ±0.5%	NARDA
R36	440-R36	" 2.46Ω ±0.5%	NARDA
R37	440-R37	" 3.16Ω ±0.5%	NARDA
R39	EB-1/2	" 36KΩ ±5%	ALLEN BRADLEY
R41	EB-1/2	" 390Ω ±5%	ALLEN BRADLEY
R42	EB-1/2	" 8.2KΩ ±5%	ALLEN BRADLEY
R44	EB-1/2	" 56KΩ ±5%	ALLEN BRADLEY
R45	EB-1/2	" 2.2KΩ ±5%	ALLEN BRADLEY
R46	EB-1/2	" 15Ω ±5%	ALLEN BRADLEY
R50	EB-1/2	" 910Ω ±5%	ALLEN BRADLEY
R51	EB-1/2	" 1.2KΩ ±5%	ALLEN BRADLEY
R54, R55	EB-1/2	" 18KΩ ±5%	ALLEN BRADLEY
R58	EB-1/2	" 360Ω ±5%	ALLEN BRADLEY
R59	EB-1/2	" 200KΩ ±5%	ALLEN BRADLEY
R60	EB-1/2	" 10Ω ±5%	ALLEN BRADLEY
R61	Type MDC	" 75KΩ ±1%	I. R. C.
RT1	28D13	Thermistor	VECO
S2	440-404	Selector Switch	NARDA
S3	440-405	Range Switch	NARDA
S4	1457	Charge Switch	CENTRALAB
T1	440-407	Transformer	NARDA
T2	440-408	Transformer	NARDA
T3	440-412	Transformer	NARDA